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ABSTRACT

Ascertaining changes in cognitive correlates of learning as students advanced through hierarchical instruction, 24 individual difference measures were obtained from 166 Navy trainees who had completed a computer-managed mastery course in electricity and electronics. Three types of cognitive characteristic measures were used in the study--tests of cognitive styles, abilities, and aptitudes. The instructional treatment consisted of the first 11 modules of the Basic Electricity/Electronics School curriculum. This involved computer managed instruction (CMI) to implement the mastery learning of the subject matter of the modules. The students self-studied and self-paced themselves through lesson modules off-line. From the tests of cognitive characteristics, principal component analysis and varimax rotation were computed, producing factor scores which were used in multiple regression analyses to predict achievement in the 11 modules of instruction. Results indicated that considerable changes occurred in the cognitive predictors of achievement as students progressed through the modules. During the acquisition of course content, the cognitive components sampled shifted noticeably in importance throughout the curriculum. These results seemed to imply that it is not only the content of instruction which matters, but also the task demanded of the students as they progress through the course that determine the nature of the relationship of cognitive style to achievement. The results have implications for research on transition from novice to expert, crystallized and fluid intelligence, task demands of instruction, and computer-managed mastery learning. (Author/KC)

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Changes in the Cognitive Components of Achievement as Students Progress
Through Sequential Instruction

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Abstract

Ascertaining changes in cognitive correlates of learning as students advanced through hierarchical instruction, 24 individual difference measures were obtained from 166 Navy trainees who completed a computer-managed-mastery course in electricity and electronics. Principal component analysis and varimax rotation were computed for cognitive characteristics producing factor scores which were used in multiple regression analyses to predict achievement in 11 modules of instruction. During acquisition of course content, cognitive components sampled shifted noticeably in importance throughout the curriculum. The results have implications for: ATI research, transition from novice to expert, crystallized and fluid intelligence, tasks demands of instruction, and computer-managed mastery learning.

Several studies have shown that aptitudes demanded by perceptual-motor tasks usually shift as students proceed to improve their performance (for reviews see Ferguson, 1965; Fleishman, 1972; Fleishman & Bartlett, 1969). Other investigations have extended this result to more cognitive learning tasks (Dunham, Guilford, & Hoepfner, 1968; Frederiksen, 1969; Gagne & Paradise, 1961; Hultsch, Nesselroade, & Plemons, 1976; Labouvie, Frohring, Baltes, & Goulet, 1973; Roberts, King, & Kropp, 1969; Dunderson, Note 1). If aptitudes required at one stage of mastery are not always similar to those needed at later stages, then some established aptitude-learning relationships may be misleading for certain instructional treatments: They would represent the importance of specific aptitudes only at those particular times when achievement was assessed. This would make it more difficult to interpret the results of aptitude-treatment-interaction (ATI) studies (Cronbach & Snow, 1977), and likely contribute to the conflicting findings of many of these investigations. Most of the research upon which this speculation is based involved the practice of laboratory learning tasks--not academic instruction.

There has been very little research on the nature of the relationship of aptitudes to achievement as students progress through scholastic instruction. The results of a recent study (Burns, 1980) suggested that certain aptitude-learning relationships are not stable throughout instruction. These findings did not support an important assumption made in ATI research: The relationship of aptitudes to achievement is stable during the course of learning for a specific instructional treatment. The curricular materials used in the Burns' investigation were hierarchical learning units describing an imaginary science which were taught and tested within a four-days time frame. Neither the subject matter nor the duration of learning, appeared to represent with sufficient fidelity real-world, school-based, instructional situations. Consequently, the results of this study were at best suggestive.

Additional data are required to help establish whether unstable aptitude-achievement relationships are general enough to warrant consideration by ATI researchers. The objective of this reported research was to determine the nature

and extent of changes in the cognitive correlates of learning as students advanced through hierarchical modules of instruction.

Approach

Subjects

The subjects were 340 individuals who graduated from recruit training at the Naval Training Center, San Diego and who were scheduled for instruction at the Basic Electricity and Electronics (BE/E) School at that Center. Before beginning BE/E orientation, the subjects were administered 12 tests--six designed to measure their cognitive styles; and six, their abilities. Test data for 20 of the subjects were discarded, since they failed to follow directions and/or to complete at least 9 of the 12 tests. Of the remaining 320, 40 failed to graduate--35 for academic reasons and 5 for nonacademic reasons. Thus, test data were available for 280 BE/E graduates.

Aptitudes of all individuals entering the Navy are measured by scores obtained on the 12 subtests of the Armed Services Vocational Aptitude Battery (ASVAB). However, when attempting to obtain this data for the subjects of this study, it was found that 108 of them, either had incomplete or missing ASVAB scores. Six additional graduates were found to have missing or incomplete data regarding module test scores which are usually maintained by the computer-managed instruction (CMI) system for all BE/E students. Thus, the final sample used in this study consisted of 166 BE/E graduates.

Cognitive Characteristic Measures

Three types of cognitive characteristic measures were used in the study--tests of cognitive styles, abilities, and aptitudes. Cognitive styles are the dominant modes of information processing which individuals typically employ when perceiving, learning, or problem solving. Abilities are the intellectual capabilities of individuals which are general and pervasive to the performance of many tasks. Aptitudes are indices used to select personnel to perform tasks which demand specific skills and to find the right person for a certain job or school.

The six tests designed to measure cognitive styles were chosen because of their implications for adaptive instruction (Kogan, 1971); and the six tests designed to measure abilities, because they represent various types of information-processing tasks (Carroll, 1976) and are relevant to the BE/E subject matter. The ASVAB subtests were selected as measures of aptitudes not only because they are typically readily available for Navy personnel, but also because they are used as a basis of assigning personnel to different Navy schools. Also, the ability and aptitude measures were included in the investigation to reflect crystallized (G_c) and fluid (G_f) intelligence (Cattell, 1971; Horn, 1976; Snow, 1977, 1980). G_c is usually indexed by tests that are allegedly indicative of traditional educational achievement, i.e., verbal, quantitative, and reasoning abilities. G_f is usually indexed by tests that are allegedly indicative of adaptation in novel learning situations, i.e., abstract, nonverbal, spatial, and figural reasoning abilities. All of the tests are (a) relatively independent, (b) moderate to high in reliability, (c) paper-and pencil in nature, and (d) fairly short in duration.

The 24 cognitive characteristic tests, their abbreviations used in the study, what they are intended to measure, the task required of the subjects, how they were scored, and the time limitations they imposed on the subjects are as follows:

Cognitive Styles.

Field-Independence vs. Field-Dependence (FILDINDP) refers to a predominant manner of approaching the environment in an analytical as opposed to a global fashion. A field independent person tends to differentiate objects or figures from their embedding backgrounds or contexts; and a field-dependent person, to experience objects or figures as part of their backgrounds or contexts. The former mode of processing reflects competence in analytical functioning together with an impersonal orientation; and the latter, less competence in analytical functioning together with a personal orientation (Witkin, Lewis, Hertzman, Machover, Meissner, & Wagner, 1954;

Witkin, Dyk, Faterson, Goodenough, & Karp, 1962; Witkin, Oltman, Cox, Erichman, Hamm, & Ringler, 1973). This dimension of style was measured by the Hidden Figures Test, Part 1 (Ekstrom, French, Harman, & Derman, 1976), a modification of the Gottschaldt figures-type test specifically designed and developed to study field independence. Within a 12-minute time period, the subject must decide--for each of 16 items--which of five geometrical figures is embedded in a complex pattern. The test score consists of the number of correct items minus a fraction of the numbers of wrong ones. Consequently, the higher the score, the more a subject can differentiate objects from the embedding contexts (i.e., the more field independent).

Conceptualizing Style (CONCSTYL) refers to the span of objects or patterns a person tends to consider in one conceptual category. It indicates the way a person organizes or sorts objects to maximize similarities or differences among them; or the range of things he treats as the same or equivalent (Kagan, Moss, & Siegel, 1960, 1963; Sloane, Gorlow, & Jackson, 1963; Wallach, 1962; Wallach & Kogan, 1965). Persons using a few broad categories in sorting tend to perceive that diverse objects are the same or equal; and those using many narrow categories, that they are different or unequal. Persons who use many categories in sorting typically show more critical judgment in recognizing ambiguities among objects or situations than those who use a few categories. This style was measured by the Clayton-Jackson Object Sorting Test I (Clayton & Jackson, 1961), which consists of a printed sheet containing 50 words--each referring to a familiar object. The objects themselves are heterogeneous in function. The subject's task is to sort those objects by writing down in columns the names of those that appear to go together. He/she is given 17 minutes to complete the task. The test score is the number of categories formed. The higher the score, the more a subject tends to differentiate when categorizing objects.

Reflectiveness-Impulsivity (REFLIMPL) reflects the tendency to act deliberately as opposed to impulsively; that is, the inclination to contemplate a course of action instead of acting on the "spur of the moment." Reflective persons typically are reserved, inhibited, slow, unemotional, and rational; and impulsive persons, spontaneous, uninhibited, hasty, impetuous, and rash. This cognitive style is primarily concerned with the degree to which a person tends to consider the validity of alternative hypotheses for solutions to problems that contain response uncertainty (Block, Block, & Harrington, 1974; Kagan & Kogan, 1970; Kagan & Messer, 1975; Messick, 1977). That is, reflective persons usually ponder several alternative possibilities prior to deciding and acting; and impulsive persons usually select and exercise the first possibility that occurs to them. This style was measured by the Impulsivity Subscale from the Personality Research Form, Form E (Jackson, 1974). The subject is presented with a series of 16 true-false statements and asked to indicate whether he feels the characteristic mentioned in each applies to him. He/she is allowed a maximum of 4 minutes to complete this test. Since the test is keyed for impulsivity, the higher the score, the more impulsive the individual.

Tolerance of Ambiguity (TOLRAMBQ) usually refers to the tendency to accept situations or issues that have alternate interpretations and outcomes, or to feel comfortable when confronted with complex issues or circumstances. A person who is tolerant of ambiguity usually perceives such situations or issues as desirable or, at least, not threatening; and a person who is not, as undesirable or threat-inducing. These latter individuals tend to reduce complex issues to simplistic "black-and-white" notions (Frenkel-Brunswick, 1949; Rydell, 1966; Rydell & Rosen, 1966). This dimension was measured by the Tolerance of Ambiguity Scale, which is included in the Self-Other Test, Form C (Rydell & Rosen, 1966). This scale contains 16 items, each

consisting of a statement about a problem or situation, and a corresponding opinion as to its nature. The subject's task is to indicate whether he mostly agrees or disagrees with the opinion. The time limit for this task is 5 minutes. The higher the subject's score, the more tolerant he is of ambiguous situations.

Category Width (CATEWIDH) refers to the consistency of the width or range of cognitive categories. When subjects are asked to estimate the two extremes of, say, the speed of birds in flight or the annual rain-fall in Washington, D. C., their breadth of categorization tends to be broad, medium, or narrow. This response may be a reflection of their risk-taking behavior. Broad categorizers are inclined to risk negative instances by including a maximum number of positive instances (Type I error); and narrow categorizers, to risk positive instances by excluding a minimum number of negative instances (Type II error). That is, broad categorizers tend to tolerate or prefer errors of inclusion; and narrow categorizers, errors of exclusion (Bruner & Tajfel, 1961; Fillenbaum, 1959; Messick & Kogan, 1965). This cognitive style was measured by the Category Width Scale (Pettigrew, 1958). The scale consists of a series of ten items, each of which states an average value for, say, the length of whales, followed by a series of numbers. The subject's task is to select the two numbers that he feels represent the two extremes of that value. He/she must complete the test in 8 minutes or less. Items are scored based on the difference between the values of the stated mean and the subject's responses. The higher the total score, the broader the category width.

Cognitive Complexity (COGCOMPX) reflects the tendency to perceive the external environment, especially the social environment, in a multi-dimensional and discriminating manner. A more cognitively complex person perceives this environment in a more differentiated manner than a less cognitively complex person (Bieri, Atkins,

Briar, Leaman, Miller, & Tripodi, 1966; Langley, 1971; Kelley, 1955; Schroder, Driver, & Streufert, 1967). The test used to measure this style was a group version of the Rep Test (Kelley, 1955), which is called the Role Construct Repertory Test (Bieri et al., 1966). The subject is presented with a grid that includes eight columns and eight rows. The columns are labelled by a distinct role type chosen to be indicative of meaningful persons in the subject's social environment, and the rows, by individual traits or characteristics. The subject writes the initials or names of eight persons who correspond to the eight role types, and then rates these persons on a Likert-like scale on all the eight traits. To ensure privacy, the subject is instructed to erase or cross out the names or initials of the persons rated when he has finished the task. This test is scored by comparing the ratings given for each person. If any two ratings agree, a score of 1 is given. The higher the total score, the less cognitively complex the subject since he is evaluating all eight persons in an identical manner.

Abilities.

Verbal Comprehension (VERBCOMP) refers to a person's capacity to understand or comprehend the English language. It has been suggested (Ekstrom et al., 1976) that this dimension may be part of a more pervasive factor that includes reading comprehension, verbal analogies, matching proverbs, grammar and syntax, and verbal relations. Results of two investigations (Haag & David, 1969; Messick & French, 1975) implied that it may be related to the facility to use words in a multiple or flexible manner. Carroll (1974, 1975) mentioned that, within an information-processing framework, this ability is mostly determined by "the lexicosemantic long-term memory store." The test employed for this cognitive ability was the Vocabulary Test, Part I (Ekstrom et al., 1976). In this 18-item test, the subject is presented with stimulus words, each followed by five other words. The subject selects the one word that has the same

or nearly the same meaning as the stimulus word. The maximum time permitted is 4 minutes. The score consists of the number of right responses, minus a fraction of the number of wrong responses. The higher the score, the greater the verbal ability.

General Reasoning (GENLREAS) is related to the cognitive capacity to select and organize information pertinent for solving specific problems. Although mathematical reasoning tests are frequently used to measure this ability, they often confound numerical facility with general reasoning ability. Werdelin and Stjernberg (1971) found, in their investigation of tests of arithmetic problems, nonmathematical logical reasoning, and number series, that the more difficult the test, the more it weighted general reasoning. Consequently, this factor could be related to the higher difficulty level of other reasoning factors (Ekstrom et al., 1976). Carroll (1974, 1975) mentioned that general reasoning was very similar to logical syllogistic reasoning because both include retrieval and serial operations. The test used to measure this ability was the Arithmetic Aptitude Test, Part I (Ekstrom et al., 1976). In this test the subject is presented with 15 arithmetic word problems, each followed by five alternative answers. The subject's task is to solve the problems in 10 minutes or less. The score consists of the number of correct answers minus a fraction of the number of incorrect answers.

Associational Fluency (ASSOFLU!) refers to the capacity to generate rapidly words that have similar meanings or some other common semantic characteristic. Nunnally and Hodges (1965) found separate subfactors for the associations of synonyms, antonyms, and objects usually seen together. Carroll (1974, 1975) indicated that associational fluency involves search of long-term memory, with particular attention directed to its semantic and associational aspects. A subject high in this ability probably has many associations tied to a word and much flexibility in interpreting similarity (Bereiter, 1960). The test used to measure this

ability was the Controlled Associations Test, Part I (Ekstrom et al., 1976). The subject is presented with four stimulus words and asked to write, within 6 minutes, as many words as possible that have the same or similar meanings as these words. The score is the number of correct words. The higher the score, the greater the associational fluency.

Logical Reasoning (LOGIREAS) is related to deducing or reasoning syllogistically from premise to conclusion or evaluating logically the correctness of a conclusion. It can be easily confounded with verbal reasoning, especially when the task involves a high level of reading. This factor is quite complex. It involves the retrieval of meanings and algorithms from long-term memory and the performance of serial operations on the materials recovered (Carroll, 1974, 1975). The test used to measure this factor was the Nonsense Syllogisms Test, Part I (Ekstrom et al., 1976). In this test, the subject is presented with 15 items, each consisting of three statements. Even though all of the statements are really nonsense, the subject is to assume that the first two statements in each item are correct. He/she must decide whether or not the third statement, which is really a conclusion drawn from the first two statements, demonstrates good reasoning. The subject has 4 minutes to complete the test. The score is the number marked correctly minus the number marked incorrectly. The higher the score, the better the reasoning ability.

Induction (INDUCTION) involves forming and testing hypotheses that will fit certain data. It requires producing concepts and evaluating hypotheses and is primarily a synthesizing or unifying process. In information-processing terms, it demands searching long-term memory for pertinent hypotheses in a general logic store. Successful performance depends on whether or not the contents of this store are sufficient to produce the solution (Carroll, 1974, 1975). The test used to

measure this ability was the Figure Classification Test, Part I (Ekstrom et al., 1976). The test includes 14 items, each comprised of two or three groups of three figures, followed by a number of stimulus figures. For each item, the subject's task is to determine (1) what the three figures in any one group have in common (e.g., shaded or unshaded, straight or curved), (2) how the groups of figures differed from one another (e.g., shaded vs. unshaded, straight vs. curved), and (3) which group of figures best corresponded to or matched each of the stimulus figures. He had 8 minutes to complete the task. The score is the number of stimulus figures classified correctly minus a fraction of the number classified incorrectly.

Ideational Fluency (IDEAFLUN) refers to the facility to generate a number of ideas about a specific topic or exemplars of a certain class of objects. The emphasis is on the quantity rather than the quality of ideas produced. It is similar to semantic originality and redefinition. According to Carroll (1974, 1975), all of these dimensions involve a search in an experiential store or episodic memory. Ideational fluency involves a rather wide search, whereas semantic originality and redefinition involve restrictions of unusualness or set breaking. The test used to measure this factor was the Topics Test, Part I (Ekstrom et al., 1976). The subject is given a specific topic and asked to list all the ideas he/she can about that topic, whether or not they seem important to him. The subject can use a word or a phrase to express each idea. He/she has a time limit of 4 minutes. The score is the number of appropriate ideas written. The higher the score, the higher the ideational fluency.

Aptitudes.

All aptitudes were measured by ASVAB subtests which are described below.

General Information (GENINFO) is an index of the developed aptitude to recognize

factual information that has accumulated from past learning experiences. It is a 20-item test of general knowledge concerning such areas as geography, sports, art, history, and first aid. The subject is instructed to read each item, and to select the best answer from four response alternatives. The time limit for this test is 7 minutes. The subject's score is determined by the number of questions answered correctly. The higher the score, the greater the general knowledge.

Numerical Operations (NUMROPER) measures how rapidly and accurately a subject can complete arithmetic operations, such as addition, subtraction, multiplication, and division. The subject is instructed to choose the correct response from four response alternatives. This is a 50-item speeded test with a time limit of 3 minutes. The score is the number correct. The higher the score, the greater the numerical facility.

Attention to Detail (ATTNDETL) was designed to measure the aptitude to perceive simple relationships, to store these relationships mentally, and to decide upon them quickly and accurately. The subject is presented with 30 items, each comprised of two lines of O's with a varied number of C's mixed in, and asked to indicate, for each item, the total number of C's in both lines. This is a 5-minute speeded test. The subject's score is the number of items marked correctly. The higher the score, the more attentive the subject is to detail.

Word Knowledge (WORDKNOL) is an index of verbal comprehension that is dependent upon the aptitude to understand written and spoken language. The subject is presented with 30 items, each consisting of an underlined word followed by four other words. For each item, the subject must decide which of the four response words has the same or nearly the same meaning as the underlined word, within a 10-minute period. His score is the number of items answered correctly. Higher scores indicate better word knowledge.

Arithmetic Reasoning (ARTHREAS) was constructed to measure general reasoning, which is dependent upon the aptitude to solve arithmetic word problems. The subject is required to solve 20 of these problems within a 20-minute period. The score is the number of items answered correctly. Higher scores indicate greater arithmetic reasoning skills.

Space Perception (SPACPERC) was constructed as an index of a subject's spatial aptitude. It entails the skill to visualize and manipulate objects in space. The subject is presented with 20 pictorial items, each consisting of flat patterns and four drawings of three-dimensional figures. Broken lines on the flat pattern indicate where it is to be folded. The subject must decide which figure could be constructed from each of the flat patterns within a 12-minute period. The score is the number of items answered correctly. The higher the score, the greater the spatial aptitude.

Mathematics Knowledge (MATHKNOL) was designed as an index of the aptitude to use mathematical relationships involved in solving problems in algebra, geometry, fractions, decimals, and exponents. The subject is required to solve 20 problems in a 20-minute period. The score is the number of correct items. Higher scores signify more mathematical aptitude.

Electronics Information (ELECINFO) is an index of the cognitive aptitude to use acquired electronic relationships, symbols, principles, and diagrams. The subject is required to answer 30 items involving electronics terminology and computations in a 15-minute period. The score is the number of correct items. Higher scores indicate more electronic aptitude.

Mechanical Comprehension (MECHCOMP) measures the aptitude to learn, comprehend, and reason with mechanical and physical concepts and principles. Familiarity with ordinary tools and mechanical relations acquired through daily experiences is a

prerequisite for adequate performance on this test. The subject is presented with 20 pictorial items and asked to indicate what the drawings represent, within a 15-minute period. The score is based on the number of correct responses. The higher the score, the more the mechanical aptitude.

General Science (GENLSCIE) measures scientific knowledge of physics and biology, and the reasoning involved to perceive relationships between scientific concepts. The subject is required to respond to 20 items on science within 10 minutes. The score is the number of correct items. Higher scores signify greater knowledge of general science.

Shop Information (SHOPINFO) is an index of an aptitude that is dependent upon knowledge about and experience with a variety of tools typically found in a ship. The subject is required to answer 20 multiple-choice items about shop practices or tool use within 8 minutes. The score is the number of items marked correctly. Higher scores indicate greater shop knowledge.

Automotive Information (AUTOINFO) was designed to measure an aptitude pertaining to the diagnosis of automobile malfunctions, the use of specific automotive parts, the operation of particular automobile components, and the knowledge of automobile terminology. The subject is required to answer 20 multiple-choice items dealing with various aspects of automobiles within 10 minutes. The score is the number correct. The higher the score, the greater the automotive knowledge.

Instructional Treatment

The instructional treatment consisted of the first 11 modules of the BE/E School curriculum, course file 69. This involved CMI to implement the mastery learning of the subject matter of the modules.

Computer-Managed Instruction.

In CMI students self-study and self-pace themselves through lesson modules

off-line, i.e., they do not directly interact with the system while learning. This is unlike computer-assisted instruction where course contents and tests are stored in the computer with which the student interacts with in real time by means of on-line terminals. Also, in CMI the computer via its distributed terminals (a) scores criterion-referenced-multiple-choice tests that the student takes off-line too; (b) interprets test results and provides feedback to each student regarding his/her performance; (c) advises the student to learn the next or alternative lesson or to remediate mastery modules; and (d) manages student records, instructional resources, and administrative data (Baker, 1978; Orlansky & String, Note 5).

Mastery Learning.

Mastery learning has many major features: (a) mastery is explained relative to the specific instructional objectives every student is required to achieve, (b) the instruction itself is structured into clearly defined learning units or modules, (c) complete mastery of each module is demanded of every student before proceeding to the next, (d) a diagnostic objectives-referenced test is administered to every student at the end of each module to provide feedback on the adequacy of the trainee's learning, (e) based upon the diagnostic information a student's original instruction is remediated and/or supplemented so that he/she can successfully master the module, and (f) time to complete each module is used as the means of individualizing instruction and thus promoting mastery of the material (Block, 1974; Bloom, 1974, 1976).

Module Booklets.

The individualized learning materials used in this study were a set of 11 hierarchical learning modules designed and developed to teach basic facts, concepts, principles, and rules regarding electricity and electronics. These modules were selected for this research since students from all electronics-related Navy ratings must master them successfully before proceeding to more specialized training. Each module was presented as a self-study booklet consisting of three to seven lessons.

To learn a lesson within a booklet, students had the option of choosing based upon their experience and preference a narrative presentation, programmed instruction, and/or straightforward summary. These alternative training treatments for a lesson could be complemented by enrichment material or the instructor if the students so desired. Learners were encouraged to use any or all of the instructional resources that they considered necessary to master the module material. The descriptive prose in each of the booklets was supplemented by many schematics, circuit diagrams, photographs of meters, and algebraic expressions. Typically, the presentation of the many facts, concepts, principles, and rules was followed by appropriate examples.

Subject-Matter Content.

The subject-matter content of each of the 11 modules' lessons was as follows:

Module 1. Electrical current--electricity and the electron, electron movement, current flow, measurement of current, and the ammeter.

Module 2. Voltage--Electromotive force from chemical action, magnetism, electromagnetic induction, AC voltage, uses of AC and DC, and measuring voltage

Module 3. Resistance--Characteristics of resistance, resistors, resistor values, and ohm-meters.

Module 4. Measuring current and voltage in series circuits--measuring current in a series circuit, voltage in a series current, and using the multimeter as a voltmeter.

Module 5. Relationships of current, voltage, and resistance--voltage, resistance, and current; Ohm's law formula, power, internal resistance, and troubleshooting series circuits.

Module 6. Parallel circuits--rules for voltage and current, rules for resistance and power, variational analysis, and troubleshooting parallel circuits.

Module 7. Combination circuits and voltage dividers--solving complex circuits, voltage reference, and voltage dividers.

Module 8. Induction--Electromagnetism, inductors and flux density, inducing voltage, and inductance and induction.

Module 9. Relationships of current, counter electromotive force, and voltage in inductance-resistance circuits--rise and decay of current and voltage, inductance-resistance time constant, using the universal time constant chart, inductive reactance, relationships in inductive circuits, and phase relationships.

Module 10. Transformers--transformer construction, transformer theory and operation, turns and voltage ratios, power and current, transformer efficiency, and semiconductor rectifiers.

Module 11. Capacitance--the capacitor, theory of capacitance, total capacitance, resistance-capacitance time constant, capacitive reactance, phase and power relationships, and capacity design considerations.

Achievement Measures.

The achievement test score for any of these sequential modules was the number of items correct on a student's first attempt at taking a mastery quiz. These end-of-module tests consisted of four-alternative-multiple-choice items ranging in number from ten to forty-five which were congruent with instructional objectives. The number of contact hours required to master the instructional material of each module was also retrieved from the CMI system for every student. The means and standard deviations of the times required by the students to complete the 11 modules were 5.56 (3.59), 6.93 (3.45), 6.34 (2.77), 8.05 (4.68), 14.27 (7.72), 9.18 (4.89), 19.83 (9.60), 6.43 (3.41), 9.58 (4.51), 6.98(4.06), and 8.55 (4.08), respectively. The average total number of contact hours for trainees to complete this specific CMI curriculum was 101.70. This represents 16.95 six-hours course days of instruction.

Statistical Analyses

A principal components analysis with no iterations (Hotelling, 1933) was computed for the 24 x 24 intercorrelation matrix of the cognitive characteristics to obtain a smaller and more manageable number of variables. The minimum eigenvalue criterion was employed to establish the number of significant principal components to be rotated for the terminal solution, i.e., only components with eigenvalues greater than or equal to one were retained. Kaiser's (1958) varimax procedure was used to rotate orthogonally the initial component solution. Derived component scores were computed for subjects and used as predictors in performing 11 multiple regression analyses. These determined the amount of variance the cognitive components accounted for in the module achievement scores. That is, the terminal rotated solution also yielded orthogonal dimensions resulting in independent component scores. Consequently, it was feasible to ascertain the relative contributions of the cognitive components to module achievement.

Results

Descriptive Statistics

The means, standard deviations, and intercorrelations for the 24 cognitive characteristics and 11 module achievement scores are presented in Table 1.

Insert Table 1 about here

Some of the correlations are noteworthy. The diagonal correlations between successive module scores did not increase monotonically. This suggested that each module's performance did not correlate the strongest with those modules that immediately preceded or followed it. As the sequential separation between modules increased, i.e., moving across the rows of the matrix to the right or down the

columns, the correlations did not decrease. This implied that the remoteness of a module from another did not necessarily lessen the relationship between them. Most of the cognitive styles measures were not significantly correlated with ability and aptitude measures. The primary exception was field independence which was related to general reasoning, associational fluency, mathematics knowledge, electronics information, and mechanical comprehension. Some of the strongest relationships existed among measures of word knowledge, electronics information, mechanical comprehension, general science, and shop information. The many significant correlations between cognitive attributes and module scores were not as strong as expected.

Component Structure of Cognitive Characteristics

The initial principal-component solution for the cognitive characteristics and its accompanying communalities, associated eigenvalues, and percent variance accounted for are shown in Table 2 for the reader's inspection.

Insert Table 2 about here

As can be seen, aptitude and ability measures are the prime contributors to the first principal-component. The seven components accounted for 60.1% of the variance of these measures.

Table 3 presents the terminal varimax solution for the cognitive attributes. Considering only those characteristics with loadings equal to or greater than .3 and listing the measures in order of their importance according to the magnitude of their weights, the derived components were interpreted as follows:

Insert Table 3 about here

The first component was defined by mechanical comprehension; shop, automotive, and electronics information; general science, word knowledge, space perception, general information, arithmetic reasoning, and verbal comprehension. The ten tests loading this component were diverse in content and probably indicative of undifferentiated general intelligence, G.

The tests contributing to the second component were numerical operations, mathematics knowledge, attention to detail, arithmetic reasoning, tolerance of ambiguity, and general reasoning. All of these measures seemed relevant to scholastic mathematical achievement. Consequently, this component was labeled crystallized mathematical intelligence, G_{cm}.

The third component was dominated by four tests of verbal educational achievement, namely: associational and ideational fluency, verbal comprehension, and word knowledge. Therefore, this component was called crystallized verbal intelligence, G_{cv}.

Four tests identified the fourth component--field independence, induction, space perception, and category width. These were primarily nonverbal reasoning tests of spatial and figural processing. It was thought that these tests represented fluid intelligence, G_f.

The fifth component was chiefly defined by four tests of conventional educational achievement in reasoning. These were general and logical reasoning, tolerance of ambiguity, and verbal comprehension. It seemed suitable to label this component crystallized reasoning intelligence, G_{cr}.

Two tests primarily loaded the sixth component: reflection-impulsivity and cognitive complexity. This component seemed to symbolize simplistic processing, P_s, because the first test loading this component was keyed for impulsivity and the second one was negatively weighted.

The seventh component was dominated by category width, conceptualizing style, and tolerance of ambiguity. Since the last two tests were negatively loaded, it appeared reasonable to call this component global processing, Pg.

Cognitive Characteristics and Module Achievement Relations

Simple and multiple correlation as well as standardized partial regression coefficients between cognitive characteristic components and module achievement scores are tabulated in Table 4. Consider the multiple correlation coefficients

Insert Table 4 about here

first. These indicate the relationships between all cognitive components and the achievement of each module. Ten of eleven multiple correlations were significant. For modules 1 and 4 through 9 these correlations were somewhat stable ranging from .31 to .37. The multiple correlations were larger than this for modules 2, 10, and 11 being between .43 and .47. These relationships are indirectly represented in Figure 1 which depicts the amount of variance of the achievement of each module

Insert Figure 1 about here

accounted for by the cognitive components. As can be seen in Figure 1, the ten significant multiple correlations indicated that the cognitive components explained 10% to 22% of the variance of module achievement.

Focusing on the individual cognitive components' contributions to the achievement of each module which are presented in Table 4 and portrayed in Figure 1, a different picture appeared. The components differed in their importance regarding

module achievement. None of the cognitive components manifested a stable contribution to achievement across all the modules. In fact, two of the components, P_s and P_g , only made trivial or random contributions to achievement. The G component accounted for a significant share of achievement in merely three modules: 2, 10, and 11. G_{cm} demonstrated no relationship to achievement in the first ten modules, but did contribute to module 11. The G_{cy} component was an important influence on achievement in no more than two modules: 2 and 5. G_f explained portions of achievement for five of the eleven modules: 2, 6, 8, 9, and 10. These significant contributions were somewhat stable for just four of the five modules ranging from .23 to .28. Lastly, the G_{cr} component manifested significant relationships to the achievement of eight modules: 1, 2, 4, 5, 6, 7, 10, and 11. These varied from a low of .16 to a high of .31 with six of these being rather stable ranging from .20 to .27. In terms of the number of significant regression coefficients, the most important components contributing to achievement through the modules were G_{cr} and G_f , respectively. Looking across the modules, there was no obvious trend--neither a steady increase nor decrease--in the number of significant components contributing to achievement. These ranged from one to four, and changed according to no discernible pattern. The relative importance of the components in terms of the amount of variance accounted for, or the magnitude of the regression coefficients, varied notably throughout the modules. Various combinations of cognitive components predicted the achievement of specific modules. Different modules drew on different components to different degrees.

When the subject matter of each of the eleven modules was classified according to the task-content matrix of the Instructional Quality Inventory (Ellis, Wulfeck, & Fredericks, Note 4), it was found that the first five modules primarily required students to remember facts, concepts, principles, and/or rules; and that the last six modules, to use concepts, principles, and/or rules. The results of the multiple regression analyses suggested that, in a relative sense, G_{cr} was more important for

remembering facts, concepts, principles, and/or rules; and G_f was more important for using concepts, principles, and/or rules.

Student achievement was determined, to some extent, by the cognitive characteristics they possessed prior to beginning their training. Within limits, student proficiency throughout the modules could be predicted by using measures of these cognitive components. Changes in the proportion of variance in student performance throughout the modules accounted for by certain cognitive components represented shifts in their emphasis during the process of acquiring the course content. These shifts in predictor patterns of cognitive components appeared to be related to whether students were required by a module to remember or use facts, concepts, principles, and/or rules. Different cognitive components seemed to contribute more or less to student achievement at distinct modules or stages of learning.

Discussion

The results clearly indicated that considerable changes occurred in the cognitive predictors of achievement as students progressed through the sequential modules of instruction. During the acquisition of course content, the cognitive components sampled shifted noticeably in importance throughout the curriculum. This was manifested by variations in the regression coefficients of particular cognitive predictors at distinct stages of learning. There appeared to be a difference in some components contributing variance at earlier and later phases of mastery. G_{CV} seemed more important during the learning of the first half of the modules; whereas, G_f seemed more important during the second half. G_{CR} , however, appeared equally important during both phases of acquisition being relatively stable in its contribution throughout most of the modules. These suggested that at early stages of acquiring complex subject matter, the G_{CV} component played somewhat of a major role. As learning continued through the modules, this cognitive component became less important as a determiner of individual differences in mastery. At the same time, G_f increased in importance as learning continued until this was one of two components that entered to a significant extent and number at the latter stages of mastery. While students progressed through the entire curriculum, G_{CR} remained nevertheless, somewhat stable in its contribution to their acquisition of the course content. It was implied that after progressing through hierarchical modules, individual differences in learning depend more on certain cognitive components and less on others than they did initially when beginning to acquire the course content. Earlier in learning the use of specific components is minimal but prerequisite for later acquisition. Yet, other cognitive components may remain rather unchanging during the mastery of the complete curriculum.

With respect to conducting ATI research, changes in the component predictor pattern over the course of learning underscored the necessity of ascertaining what aptitudes are contributing to acquisition at distinct stages. It was highly likely that the cognitive processing involved in the initial phases of learning differed from the processing at terminal phases of acquisition. This suggested the requirement for protocol analyses of the cognitive processing involved in early, intermediary, and later phases of learning. It seemed possible that particular aptitudes contributing to learning at distinct stages reflect the presence of prerequisite cognitive competencies, schemata, knowledges, and learning sets required to acquire the subject matter at particular phases of mastery.

The instability of the relationships of some cognitive components across distinct stages of learning suggested the importance of concentrating on the process of change from ignorance to competence. Glaser (1976) has aptly explained the transformation from novice to expert during the course of mastering complex subject matter or intricate skill as follows:

- (a) Variable, awkward, and crude performance changes to performance that is consistent, relatively fast, and precise. Unitary acts change into larger response integrations and overall strategies.
- (b) The contexts of performance change from simple stimulus patterns with a great deal of clarity to complex patterns in which information must be abstracted from a context of events that are not all relevant.
- (c) Performance becomes increasingly symbolic, covert, and automatic. The learner responds increasingly to internal representations of an event, to internalized standards, and to internalized strategies for thinking and problem solving.
- (d) The behavior of the competent individual becomes increasingly self-sustaining in terms of skillful employment of the rules when they are applicable and subtle bending of the rules in appropriate situations. (p. 9)

Burns (1980) mentioned that it is feasible that alterations in aptitude demands through learning may form the basis of the transition from novice to expert performance. In attempting to account for the nature of such shifts, he hypothesized that instructional treatments are composed of two distinct origins of aptitude requirements: those related to the method of instruction, those related to the content of instruction. Each of these sources demands a specific type of aptitude. It was postulated that the method of instruction primarily requires the G_C aptitude, and the content, the G_f aptitude.

According to Snow (1980), G_C , Cattell's (1971) crystallized ability, represents a general dimension of measures which are good predictors of conventional educational achievement or scholastic ability, e.g.: verbal, quantitative, vocabulary, reading comprehension, information, mathematical, and prior scholastic achievement. G_f , Cattell's (1971) fluid ability, represents another general dimension of measures which probably represents assembly and control processes necessary to structure adaptive strategies for solving novel and immediate problems, e.g.: abstract, spatial, figural, and nonverbal reasoning tests.

In attempting to answer why G_C measures are often better predictors of learning outcome than G_f measures, Snow (1980) speculated:

One reason may be that G_C represents the long-term accumulation of knowledge and skills, organized into functional cognitive systems by prior learning, that are in some sense crystallized as units for use in future learning. Because these are products of past education, and because education is in large part accumulative, transfer relations between past and future learning are assured. The transfer need not be primarily of specific knowledge but rather of organized academic learning skills. Thus G_C may represent prior

assemblies of performance processes retrieved as a system and applied anew in instructional situations not unlike those experienced in the past, whereas G_f may represent new assemblies of performance processes needed in more extreme adaptations to novel situations. The distinction, then, is between long-term assembly for transfer to familiar new situations versus short-term assembly for transfer to unfamiliar new situations. (p. 37)

This distinction between G_c and G_f led Burns to theorize that since G_c confers pervasive learning skills--not specific knowledge--then G_c itself transcends the particular content of instruction. To the extent that this type of instruction had been experienced by students previously, G_c would inculcate a general learning set to process and interpret this kind of instruction. Consequently, Burns posited that G_c would manifest a nearly stable relationship over the course of learning if there were no pronounced changes in the method of instruction. This could not be so with G_f . But it was possible, speculated Burns, that the processing reflected by G_f be required periodically and differentially by the content of instruction. Because the content of instruction usually changes during a course, it was reasonable to speculate the G_f -learning relationships demonstrate instability as students progressed through a particular curriculum, from novices to experts. Burns hypothesized that it was for these reasons that G_c typically manifests more consistent ATI results than specialized aptitudes like G_f (Cronbach & Snow, 1977).

In this present study it was found that both G_f and G_{c_r} demonstrated somewhat stable relationships to achievement. However, G_f was rather stable only for the second half of instruction; whereas, G_{c_r} was rather stable for approximately and primarily the first two-thirds of instruction. The content of the first five modules principally required students to remember facts, concepts, principles, and/or rules; and the last six modules to use, concepts, principles, and/or rules. These results

seemed to imply that it is not only the content of instruction which matters, but also the task demanded of the students as they progress through the course that determine the nature of the relationship of G_f to achievement. The content of instruction changed from one module to the next throughout the entire course. Nevertheless, G_f exhibited a fairly stable relationship to mastery for the second part of the curriculum. The changing course content had no apparent impact upon the stability of G_f . What seemed to be more important though regarding G_f was the type of processing task required of the students. If the cognitive task demands remained more or less constant, G_f 's relationship to achievement would remain more or less stable. Possibly, in order to perform a particular processing task, students would have to resort to the prerequisite cognitive competencies, schemata, structures, knowledges and representational systems which are assessed by specific aptitudes. If the task demands do not change, then the aptitude requirements do not change. Conversely, if the task requirements are altered, then the aptitude demands are altered. This interpretation regarding G_f differs from Burns' speculations.

In so far as G_c is concerned, the data obtained in this study seemed to suggest that G_{c_r} is independent of course content while being dependent upon task demands as well as the method of instruction. It was found that G_{c_r} exhibited a fairly stable relationship to achievement throughout the earlier part of the curriculum. The tasks required of the students during this part of the course involved primarily remembering facts, concepts, principles, and/or rules. The method of instruction remained the same while the contents of each module varied through the entire curriculum. The latter part of the course tasked students with using concepts, principles, and/or rules. It was during this final phase of instruction when the relationship of G_{c_r} to learning became unstable. With the method of instruction and task demands constant while the content changed during the initial two-thirds of the course, the relationship of G_{c_r} to achievement was somewhat stable. In the

final third of the curriculum, the method of instruction was still constant while the content and task requirements changed. It was the introduction of change in task demands that was associated with instability of G_{Cr} 's relationship to learning. This implied to some extent that the association of G_{Cr} to achievement was contingent upon task requirements and the method of instruction while being unsubordinated to course contents. This speculation differed from Burns' suppositions.

The CMI system employed to implement mastery learning of the basic electricity and electronics curriculum used in this study, more likely than not, can be considered a "new" learning situation in Snow's (1980) scheme of things:

What constitutes a "new" learning situation is not really clear. But one can predict that as an instructional situation involves combinations of new technology (e.g., computerized instruction, or television), new symbol systems (e.g., computer graphics or artistic expressions), new content (e.g., topological mathematics or astrophysics), and/or new contexts (e.g., independent learning, collaborative teamwork in simulation games), G_f should become more important and G_c less important. (p. 59)

Computer-managed instruction can be viewed as a relatively new technology. The comprehension of many circuit schematics and the solution of numerous algebraic equations can be thought of as new symbol systems. The perception of several relationships among voltage, resistance, and current as well as the reduction of complicated circuits to more simple ones can be conceived as representing new content. Lastly, the self-study and -pacing together with mastery learning can be regarded as new contexts. According to Snow, the relationship of G_c to achievement should be stronger in ordinary educational environments. This has been established in much of the ATI research (Cronbach & Snow, 1977).

If the typical instructional treatment is altered as in computer-managed mastery learning, then the strength of the association of G_C to learning is lessened and an ATI will likely appear. Consequently, students who lack well-developed, conventional, academic aptitudes will benefit from the unorthodox, educational treatment; while those who amply possess these skills may not be able to apply them. Since computer-managed mastery learning is: individualized instruction based on carefully defined objectives, hierarchical in its content, modular in its presentation and assessment, with diagnostic achievement tests and immediate feedback on student progress; it structures, segments, and directs learning for lower-aptitude students—doing for them what they cannot do well for themselves. Snow maintained that this unconventional instructional treatment is probably dysfunctional for more apt students: those that can organize and control their own learning because of the nature of the cognitive processing required and acquired previously by conventional, educational experiences. Therefore, G_C aptitude is probably of no particular advantage in novel instructional situations like computer-managed mastery learning. Within this context it is expected, stated Snow, that G_f would be associated with achievement in innovative instructional situations—different from those students experienced in the past. In these novel educational environments G_C will likely be irrelevant, and G_f , relevant. The data obtained in this study, however, demonstrated that not only is G_f pertinent to learning in new instructional situations but so is G_C , i.e., its components. This suggested that some unconventional educational settings are not necessarily dysfunctional for better abled students. It seems that in these situations they can just as easily exercise and capitalize upon those skills developed and applicable in more traditional instructional situations.

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Footnotes

Opinions and assertions contained herein are those of the author and are not to be construed as official or reflecting the views of the Department of the Navy or Defense.

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Table 1

Means, Standard Deviations, and Intercorrelations for the
24 Cognitive Characteristics and 11 Module Achievement Scores

Measure	M	SD	Mod 1	Mod 2	Mod 3	Mod 4	Mod 5	Mod 6	Mod 7	Mod 8	Mod 9	Mod 10	Mod 11
Mod 1	23.54	1.53											
Mod 2	26.15	2.80	.41										
Mod 3	17.46	1.50	.10	.19									
Mod 4	9.07	.96	.29	.27	.19								
Mod 5	27.87	2.25	.31	.37	.22	.31							
Mod 6	19.60	2.85	.17	.29	.18	.14	.48						
Mod 7	22.07	4.35	.10	.16	.30	.26	.19	.36					
Mod 8	16.74	2.17	.34	.42	.25	.22	.33	.34	.24				
Mod 9	14.87	1.96	.27	.34	.22	.27	.27	.39	.26	.50			
Mod 10	15.08	1.61	.43	.44	.23	.25	.43	.28	.23	.47	.35		
Mod 11	15.16	1.88	.34	.31	.22	.24	.37	.33	.33	.38	.34	.38	
FILDINDP	5.25	3.85	.12	.25	.13	.14	.17	.25	.08	.18	.22	.21	.24
CONCSTYL	12.71	4.08	.04	.17	-.02	-.06	.07	.14	.03	.11	.22	.06	-.06
REFRIMPL	3.37	3.16	.05	-.07	.06	.00	-.15	-.10	-.07	-.10	-.13	.02	-.02
TOLRAMBQ	5.69	2.01	.00	.07	-.03	.14	.06	-.07	-.10	-.07	-.03	-.05	-.05
CATEWIDH	31.72	9.52	.17	.04	.08	.07	.11	.09	.02	.08	.05	.28	.21
COGCOMPX	72.32	17.90	-.06	-.03	-.11	-.09	-.01	.00	.06	-.05	-.11	-.10	-.15
VERBCOMP	9.06	3.21	.23	.30	.13	.11	.28	.12	.09	.18	.11	.24	.14
GENLREAS	8.27	2.87	.24	.31	.04	.21	.23	.25	.24	.18	.13	.23	.32
ASSOFLUN	11.01	4.96	.15	.27	.06	.10	.18	.10	.03	.17	.12	.15	.15
LOGIREAS	2.79	4.54	.24	.20	.08	.15	.20	.19	.30	.20	.17	.20	.34
INDUCTON	59.64	16.77	.06	.06	-.06	.05	-.00	.10	.06	.22	.10	.09	.07
IDEAFLUN	11.47	4.12	.07	.18	-.15	-.01	.14	.02	-.07	.01	.15	.04	.18
GENLINFO	58.80	6.96	.13	.26	.04	.01	.06	.04	-.02	.14	.10	.21	.11
NUMROPER	54.11	7.44	.06	.07	-.07	.02	.04	-.05	.18	.02	.08	-.01	.12
ATTNDETL	51.19	9.52	.13	-.03	.02	-.06	-.07	-.06	.05	-.09	.02	-.08	.05
WORDKNOL	59.43	6.37	.17	.19	-.03	-.00	.17	.07	-.09	.10	.10	.17	.13
ARTHREAS	60.33	8.47	.15	.07	-.02	.02	.08	.13	.02	.08	.06	.10	.22
SPACPERC	56.10	11.26	.06	.01	.03	.12	.02	-.04	-.01	.11	.04	.09	.01
MATHKNOL	60.57	8.16	.23	.20	-.04	.10	.21	.20	.18	.21	.17	.16	.23
ELECINFO	60.63	6.36	.07	.25	.08	.22	.07	.15	.13	.24	.21	.23	.15
MECHCOMP	59.68	6.75	.16	.22	.00	.14	.17	.26	.13	.20	.18	.23	.20
GENLSCIE	60.40	7.63	.18	.24	.05	.15	.12	.19	.06	.18	.18	.15	.16
SHOPINFO	57.81	6.81	.08	.05	-.04	.07	.05	.07	-.00	.04	-.02	.10	.13
AUTOINFO	57.52	8.13	.19	.27	.10	.13	.23	.08	.06	.16	.13	.27	.20

Note. $r(164) \geq .15$; $p < .05$.

Table 1 cont

FILDINDP	CONCSTYL	REFLIMPL	TOLRAMBQ	CATEWIDH	COGCOMPX	VERBCOMP	GENLREAS	ASSOFLUN	LOGIREAS	INDUCTON	IDEAFLUN	GENLINFO
----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------

.12												
-.11	-.15											
.07	.08	.01										
.13	-.05	.15	-.05									
-.11	.00	-.21	-.06	-.19								
.12	.11	-.04	.12	.25	-.13							
.20	.10	-.01	.17	.17	-.08	.35						
.16	.05	-.05	.12	.13	.03	.41	.17					
.09	.05	-.13	.05	.17	.03	.22	.36	.10				
.19	.11	-.16	-.06	.19	.05	.14	.15	.16	.04			
-.02	.02	.05	.01	.07	.01	.22	.18	.39	.05	.17		
.05	.00	.10	.03	.09	-.13	.34	.18	.20	.18	-.03	.15	
.02	.04	-.14	-.06	.10	.03	.18	.31	.05	.11	.06	.26	.16
-.02	.02	-.04	-.12	.08	-.00	.00	.03	-.02	.10	.10	.08	-.04
-.00	.08	.01	.03	.07	-.07	.54	.15	.30	.12	.07	.22	.43
.04	-.00	-.02	.03	.07	-.11	.19	.30	.03	.25	.03	.09	.26
.13	-.05	.10	.07	.06	-.11	-.01	.09	.12	-.02	.02	-.01	.13
.25	.13	-.06	.05	.12	-.02	.26	.35	.13	.23	.15	.14	.20
.21	.03	-.10	.04	.10	.04	.29	.18	.15	.16	.13	.07	.37
.26	.07	.04	-.03	.12	.01	.20	.26	.14	.16	.21	.15	.37
.03	.07	-.03	.14	.10	.01	.39	.22	.21	.20	.04	.10	.35
-.03	-.11	-.11	.04	.05	-.01	.24	.12	.02	.12	-.11	.07	.31
.10	.05	-.11	.03	.14	-.05	.31	.16	.03	.16	.03	.11	.35

Table 1 cont

NUMROPER	ATTNDETL	WORDKNOL	ARTHREAS	SPACPERC	MATHKNOL	ELECINFO	MECHCOMP	GENLSCIE	SHOPINFO
.33									
.21	.01								
.36	.10	.38							
.07	-.03	.12	.20						
.41	.14	.32	.47	.10					
.10	-.10	.42	.21	.25	.40				
.17	-.02	.42	.29	.34	.31	.53			
.13	-.09	.60	.41	.17	.43	.51	.47		
.11	-.06	.34	.25	.17	.15	.43	.52	.41	
.10	-.11	.29	.21	.14	.19	.47	.50	.34	.53

Table 2

Initial Principal-Component Solution, Communalities (h^2), Associated Eigenvalues, and Percent Variance for the Cognitive Characteristics

Cognitive Characteristic	Initial Solution							h^2
	1	2	3	4	5	6	7	
FILDINDP	.24	.20	-.05	.54	.40	-.07	-.07	.56
CONCSTYL	.10	.21	.07	.38	-.10	-.24	-.44	.46
REFLIMPL	-.10	-.15	.22	-.49	.58	.11	-.06	.66
TOLRAMBQ	.09	-.01	.41	.18	.01	-.54	.12	.51
CATEWIDH	.20	.14	.03	.02	.41	.45	.42	.60
COGCOMPX	-.07	-.02	-.17	.26	-.58	.25	.08	.51
VERBCOMP	.56	.18	.51	-.02	-.04	-.05	.10	.61
GENLREAS	.46	.42	-.01	.08	.14	-.32	.32	.63
ASSOFLUN	.32	.29	.59	.12	-.10	.24	-.03	.63
LOGIREAS	.37	.20	-.09	.12	-.03	-.20	.55	.55
INDUCTON	.20	.39	-.02	.43	.12	.45	-.13	.60
IDEAFLUN	.28	.37	.34	-.21	-.22	.33	-.00	.53
GENLINFO	.56	-.16	.21	-.24	.05	-.01	-.02	.44
NUMROPER	.39	.49	-.34	-.32	-.20	-.03	-.01	.65
ATTNDETL	.03	.45	-.36	-.25	-.09	.16	.00	.43
WORDKNOL	.70	-.04	.27	-.24	-.14	.04	-.27	.71
ARTHREAS	.69	.18	-.28	-.24	.07	-.19	-.11	.70
SPACPERC	.51	-.24	-.30	.15	.37	.05	-.16	.59
MATHKNOL	.70	.33	-.28	-.10	.04	-.18	-.16	.74
ELECINFO	.67	-.29	-.02	.23	.00	.13	-.07	.61
MECHCOMP	.73	-.25	-.16	.12	.11	.21	-.09	.70
GENLSCIE	.73	-.18	.09	-.06	-.08	-.09	-.17	.62
SHOPINFO	.59	-.49	-.11	-.09	-.20	.02	.22	.69
AUTOINFO	.61	-.43	-.06	.14	-.21	.08	.27	.71
Associated Eigenvalue	5.42	2.02	1.64	1.50	1.42	1.31	1.14	
Percent Variance	22.6	8.4	6.9	6.2	5.9	5.4	4.7	

Note. Only factors with associated eigenvalues greater than or equal to 1.0 are tabulated. This minimum eigenvalue criterion ensures that only factors accounting for at least the amount of total variance of a single variable are significant.

Table 3

Terminal Varimax Solution for the Cognitive Characteristics

Cognitive Characteristic	Terminal Solution						
	1	2	3	4	5	6	7
FILDINDP	.10	-.05	-.06	.68	.26	.09	-.11
CONCSTYL	-.02	.02	.09	.33	.02	-.10	-.58
REFLIMPL	-.04	-.08	.04	-.11	-.21	.73	.28
TOLRAMBQ	-.01	-.32	.13	-.08	.50	.13	-.34
CATEWIDH	.07	.03	.16	.32	.14	.14	.66
COGCOMPX	.01	.01	.02	-.04	-.13	-.70	.02
VERBCOMP	.30	-.00	.62	.03	.35	.12	-.06
GENLREAS	.11	.30	.13	.19	.68	.09	-.00
ASSOFLUN	.07	-.08	.75	.20	.09	-.03	-.02
LOGIREAS	.15	.16	.02	.04	.66	-.15	.20
INDUCTON	-.01	.14	.27	.68	-.10	-.18	.11
IDEAFLUN	.01	.24	.67	-.03	-.04	-.06	.11
GENLINFO	.52	.06	.29	-.13	.09	.24	.00
NUMROPER	.09	.77	.13	-.05	.15	-.07	-.02
ATTNDETL	-.17	.61	.01	.03	-.05	-.10	.14
WORDKNOL	.59	.20	.50	-.09	-.04	.15	-.20
ARTHREAS	.50	.59	.03	.05	.22	.20	-.13
SPACPERC	.59	.09	-.24	.37	-.02	.20	.03
MATHKNOL	.43	.63	.08	.20	.25	.11	-.20
ELECINFO	.73	-.05	.10	.23	.04	-.09	-.01
MECHCOMP	.78	.12	.05	.27	-.02	.00	.09
GENLSCIE	.70	.13	.24	-.02	.09	.08	-.21
SHOPINFO	.75	-.02	-.03	-.26	.13	-.15	.15
AUTOINFO	.74	-.10	.03	-.08	.20	-.28	.16

Table 4

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Simple Correlation and Standardized Partial Regression Coefficients Between
Cognitive Characteristic Components and Module Achievement Scores

Component	Module Scores										
	Mod 1	Mod 2	Mod 3	Mod 4	Mod 5	Mod 6	Mod 7	Mod 8	Mod 9	Mod 10	Mod 11
G	.13	.19*	.05	.13	.10	.16	.06	.20	.14	.23**	.17*
G _{cm}	.15	.03	-.07	-.04	.05	.04	.14	.02	.09	-.00	.19*
G _{cv}	.12	.25**	-.04	-.01	.17*	.02	-.08	.08	.10	.10	.07
G _f	.10	.17*	.10	.14	.11	.25**	.14	.28**	.23**	.23**	.15
G _{cr}	.20*	.24**	.11	.23**	.27**	.16*	.23**	.13	.11	.20*	.31**
P _s	.09	.02	.13	.07	-.03	-.03	-.11	-.02	-.02	.11	.07
P _g	.08	-.13	.07	.03	-.04	-.03	.08	-.01	-.11	.13	.15
R	.34**	.45**	.23	.31*	.36**	.35**	.34**	.37**	.34**	.43**	.47**

Note. Since the component scores are uncorrelated in the sample, the simple correlation coefficients are also the standardized partial regression coefficients for predicting module achievement scores from the seven cognitive characteristic components.

* $p < .05$

** $p < .01$

Figure Caption

1. The amount of variance of the achievement of each module accounted for by the cognitive components.

